07 Chemical Energetics II

Set A Foundations

Name	Time 1 hour	Total 34 marks	Score ____ / 34

A Data Booklet may be used.

A From the lesson

7 MARKS

1 COMMON Find $\Delta H_{sol}(KCl)$, given $LE(KCl) = -711$, $\Delta H_{hyd}(K^+) = -322$ and $\Delta H_{hyd}(Cl^-) = -381$ kJ mol^{-1}.

[1]

/1

Source: Learners' Alley, Chemical Energetics II slides

2 CHALLENGE Which ion has the more exothermic ΔH_{hyd}, Mg^{2+} or Na^+? Explain.

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[2]

/2

Source: Learners' Alley, Chemical Energetics II slides

3 COMMON For the Haber process, $\Delta H = -92$ kJ mol^{-1} and $\Delta S = -199$ J mol^{-1} K^{-1}. Is it spontaneous at 298 K?

[2]

/2

Source: Learners' Alley, Chemical Energetics II slides

4 Baking powder releases CO_2 on heating: $2NaHCO_3(s) \rightarrow Na_2CO_3(s) + H_2O(g) + CO_2(g)$, $\Delta H = +130$ kJ mol^{-1}, $\Delta S = +335$ J mol^{-1} K^{-1}. Above what temperature is this spontaneous?

[2]

/2

Source: Learners' Alley, Chemical Energetics II slides

B Practice

27 MARKS

5 COMMON For the reaction $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$, $\Delta H = -92$ kJ mol^{-1}. Which statement about the forward reaction is correct?

A It is spontaneous only at low temperature.
B It is spontaneous only at high temperature.
C It is not spontaneous at any temperature.
D It is spontaneous at all temperatures.

Answer [ ] **[1]**

/1

Source: 2024 DHS J2 Prelim P1 Q10

6 Use of the Data Booklet is relevant to this question. When water vaporises, 40.7 kJ mol^{-1} of heat is required. What is the entropy change when 72 g of water boils at 100 °C?

A -436 J K^{-1} **B** -109 J K^{-1} **C** $+109$ J K^{-1} **D** $+436$ J K^{-1}

Answer [ ] **[1]**

/1

Source: IJC 2017 Promo, via EJC 2022 Chemical Energetics Topical Revision, Q20

7 Magnesium chloride is one of the most abundant salts in sea water.

lattice energy of $MgCl_2(s)$	-2521 kJ mol^{-1}
enthalpy change of formation of $MgCl_2(s)$	-641 kJ mol^{-1}
enthalpy change of formation of $Mg^{2+}(aq)$	-467 kJ mol^{-1}
enthalpy change of formation of $Cl^-(aq)$	-167 kJ mol^{-1}

(a) Use relevant data above to calculate a value for the enthalpy change of solution of magnesium chloride.

[2]

(b) Use your answer to explain why $MgCl_2$ is very soluble in water.

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[1]

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Source: EJC 2022 JC1 Chemical Energetics Tutorial, A6

8 COMMON Assume the pressure of each system remains constant throughout each process.

(a) Explain what is meant by the term entropy of a chemical system.

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[1]

(b)(i) Describe and explain how the entropy of each of the following systems will change during the stated process.
1 mol of $Cl_2(g)$ at 298 K is added to 1 mol of $N_2(g)$ at 298 K.

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[1]

(ii) 1 mol of $Cl_2(g)$ at 298 K is heated to 373 K.

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[1]

(iii) 1 mol of $Cl_2(g)$ at 298 K is reacted with iodine: $Cl_2(g) + \frac{1}{3}I_2(s) \rightarrow \frac{2}{3}ICl_3(l)$

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[1]

(iv) 1 mol of $Cl_2(g)$ at 1000 K is photolysed: $Cl_2(g) \rightarrow 2Cl\bullet(g)$

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[1]

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Source: EJC 2022 JC1 Chemical Energetics Tutorial, B8

9 **(a)** Given that the lattice energy of lithium chloride is −843 kJ mol^{-1} and its hydration energy is −883 kJ mol^{-1}, calculate the enthalpy change of solution of lithium chloride.

[1]

(b) 50.0 cm^3 of water was placed in a thin, well-lagged calorimeter of negligible heat capacity. The temperature of the water was 18.2 °C. 3.00 g of potassium chloride, KCl, was added and the mixture well stirred until all the crystals had dissolved. The minimum temperature reached was 14.9 °C. Calculate the enthalpy change of solution of potassium chloride. (Specific heat capacity of water = 4.20 J g^{-1} K^{-1})

[2]

(c) Comment on the results obtained in (a) and (b).

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Source: RJC H2 Chemistry Tutorial 5a (Chemical Energetics I), Q7(b) to (d)

10 Nitroglycerin, $C_3H_5(NO_3)_3$, decomposes on ignition: $C_3H_5(NO_3)_3(l) \rightarrow \frac{3}{2}N_2(g) + \frac{1}{4}O_2(g) + 3CO_2(g) + \frac{5}{2}H_2O(g)$. The standard enthalpy change of this decomposition is −1423 kJ mol^{-1}.

(a) Calculate $\Delta G^{\ominus}$ at 298 K for this decomposition, given that $\Delta S^{\ominus}$ = +208 J K^{-1} mol^{-1}. Hence, predict the spontaneity of the reaction at 298 K.

[2]

(b) Is the reaction spontaneous at all temperatures? Explain.

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Source: 2019 CJC J1 Promo P2 Q4(c) and (d)

11 COMMON Dinitrogen pentoxide, N_2O_5, can be produced in a car engine by the following reaction sequence.

I	$N_2(g) + O_2(g) \rightarrow 2NO(g)$	$\Delta H^{\ominus} = +180\ kJ\ mol^{-1}$, $\Delta S^{\ominus} = +24.8\ J\ mol^{-1}\ K^{-1}$
II	$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$	$\Delta H^{\ominus} = -114\ kJ\ mol^{-1}$
III	$2NO_2(g) + ½O_2(g) \rightarrow N_2O_5(g)$	$\Delta H^{\ominus} = -110\ kJ\ mol^{-1}$

(a) Explain why reaction I does not take place at standard conditions but occurs in the car engine.

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(b) Predict the sign of $\Delta S^{\ominus}$ in reaction II. Explain your answer.

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Source: NJC 2018 Promo, via EJC 2022 Chemical Energetics Topical Revision, Q40(i) and (ii)

12 CHALLENGE The following data relate to the energy changes which occur when sodium hydroxide, NaOH, and magnesium hydroxide, $Mg(OH)_2$, dissolve in water.

	sodium	magnesium
hydration energy of metal ion / kJ mol^{-1}	−390	−1890
lattice energy of metal hydroxide / kJ mol^{-1}	−896	−2995
enthalpy change of solution of metal hydroxide / kJ mol^{-1}	−44	x
extent of hydration of metal ion (average number of attached water molecules per metal ion)	5	15

(a) Explain why the hydration energy of Mg^{2+} is more exothermic than that of Na^{+}.

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(b) Use the data above to calculate x, the enthalpy change of solution of $Mg(OH)_2$.

[2]

(c) Solubility is also controlled by the entropy change which accompanies dissolution. Use the extent of hydration from the table to compare qualitatively the entropy changes of solution of $Mg(OH)_2$ and NaOH.

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(d) Suggest and explain one other factor which contributes to the total entropy change when $Mg(OH)_2$ dissolves in water.

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Source: EJC 2022 JC1 Chemical Energetics Tutorial, B9